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STRATA CONTROL INVESTIGATIONS IN THE SYDNEY COALFIELD

Quarterly Report December 31, 1982

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Cape Breton Coal Research Laboratory

December 1982

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STRATA CONTROL INVESTIGATIONS IN THE SYDNEY COALFIELD

Quarterly Report December 31, 1982

by

P. Cain* and T. Aston*

SUMMARY

The report reviews the progress and results of Strata Control Investigations in the Sydney Coalfield for the period October 1 to December 31, 1982. It is intended to be the first of a series of quarterly reports detailing investigation design, implementation and results from various locations in the coalfield, and it is written with the dual purpose of reporting scientific findings and assisting in the more practical aspects of mine planning and operation.

Four major topics are discussed, namely, the trial of a rock stress indicator at Lingan Colliery; the design, implementation and preliminary results from an investigation site to measure gateroad deformation in the 3W District at Lingan; an assessment of roof fall studies at Prince Mine, and a review of present activity on the Donkin-Morien Project.

Lastly, a list of objectives for the next quarter is presented.

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ENQUÊTES SUR LE CONTRÔLE DES STRATES DANS LES VEINES DE CHARBON DE SYDNEY

Rapport Trimestriel du 31 décembre 1982

par

P. Cain* et T. Aston*

SOMMAIRE

Le présent rapport examine les progrès et les résultats des enquêtes sur le contrôle des strates dans les veines de charbon de Sydney, pour la période du 1er octobre au 31 décembre 1982. Il représente le premier d'une série de rapports trimestriels étudiant en détail la conception de l'enquête, sa mise en oeuvre et les résultats obtenus, à partir de divers emplacements dans la veine de charbon. Il est rédigé pour les deux raisons suivantes: rapporter les découvertes scientifiques et faciliter les aspects pratiques de la planification minière et de sa mise en opération.

On y discute de quatre principaux sujets, notamment la mise à l'essai d'un indicateur de la tension dans les roches à la houillère Lingan; la conception, la mise en oeuvre et les résultats préliminaires d'un site d'enquête, pour mesurer la déformation de la voie de roulage dans le district 3W à Lingan; une évaluation d'études sur l'éboulement de toit à Prince Mine, et finalement un examen des activités en cours du projet Donkin-Morien.

Pour conclure, on présente une liste d'objectifs pour le prochain trimestre.

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INTRODUCTION

Despite the long history of coal mining in the Sydney Coalfield, and the problems peculiar to it, there is very little published information concerning strata control practice and problems. Most of what there is dates from the late 1950's and addresses practical problems associated with innovative methods.

Recently many countries have realized the value of the routine application of strata mechanics investigation techniques to monitor the behaviour of coalfaces and gateroads. This approach allows for amelioration of support systems and identification of problems which can then be dealt with before they become a serious threat to safety and production.

The establishment of a Coal Research Laboratory in Sydney, Nova Scotia, to service the needs of the Atlantic provinces has provided an opportunity to establish strata control monitoring and to carry out investigations into innovative machinery and methods. In the initial stages such work will be necessarily limited by shortfalls in personnel, expertise and equipment. It is hoped that within a few years, and with the cooperation of the Cape Breton Development Corporation (CBDC), a strata mechanics research facility with sufficient background data on support behaviour in the coalfield and a firm grasp of problems in the pits will be providing significant input to the planning process.

The task of collecting this background information has recently begun, and this report represents the first results obtained. It is hoped by the authors that this and subsequent reports will be of use both to fellow researchers and to CBDC personnel actively involved in the running and planning of the mines in the Sydney Coalfield.

LINGAN COLLIERY

Two projects were initiated at Lingan Colliery in the last quarter. The first, which has been completed, was the testing of a rock stress indicator, the 'StressAlert', manufactured by McPhar Mine Systems, of Toronto. The second, which is expected to continue and expand, was the programme to assess deformation processes in longwall gateroads. Results obtained from both projects are reported below.

UNDERGROUND TRIALS WITH A ROCK STRESS MONITOR

In October, 1982, CBDC were invited by McPhar Mine Systems Inc., of Toronto, to test the McPhar 'StressAlert' rock stress monitor in the Sydney Coalfield. In order to assess the performance of the instrument, a test programme of two days duration was planned at Lingan Colliery involving personnel from CBDC, CBCRL and McPhar Mine Systems.

The operation of the rock stress monitor and test programme undertaken have been described in detail elsewhere (1). In the following paragraphs the operation of the instrument, the scope of the investigation, results and recommendations are summarized.

The Operation of the Rock Stress Monitor

The 'StressAlert' Rock Stress Monitor consists of two functional components (Fig. 1). A sensor and a preamplifier are fitted to a spring-loaded assembly for mounting to a roof bolt or other fastening. This unit detects seismic events over a radius of 150 m, and the signals are fed to the second component, a micro-processor console.

The microprocessor, powered by a rechargeable battery unit, filters the incoming signals to exclude all extraneous noise and processes them to determine the number of seismic events occurring in a sixty second interval and the corresponding 'stress factor', ΔS, which is derived by dividing an empirical value of event energy by the number of events in each time period. 'Warning' or 'Alert' states are activated if preset levels are exceeded.

Extensive field trials in the U.S.A. under the auspices of the USBM have indicated that the 'StressAlert' rock stress meter can indicate the likelihood of a roof fall occurring fairly accurately, although the warning period is irregular.

Field Investigations

Field investigations with the rock stress meter were carried out at three sites (Fig. 2). These were:

1. The room and pillar section of Lingan Colliery
2. The face-end of the 4W Face at the Materials level
3. The face-end of the 3W Face at the Coal Road level

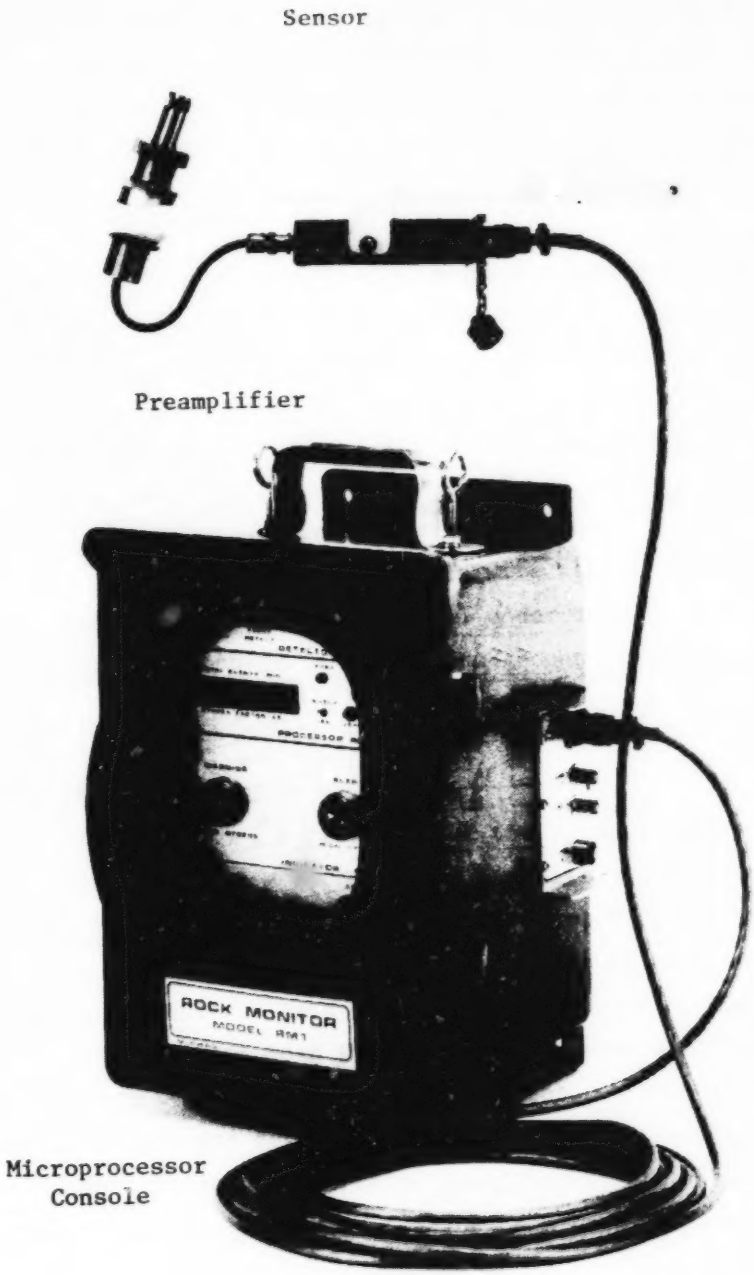


Fig. 1 - The 'StressAlert' rock stress monitor

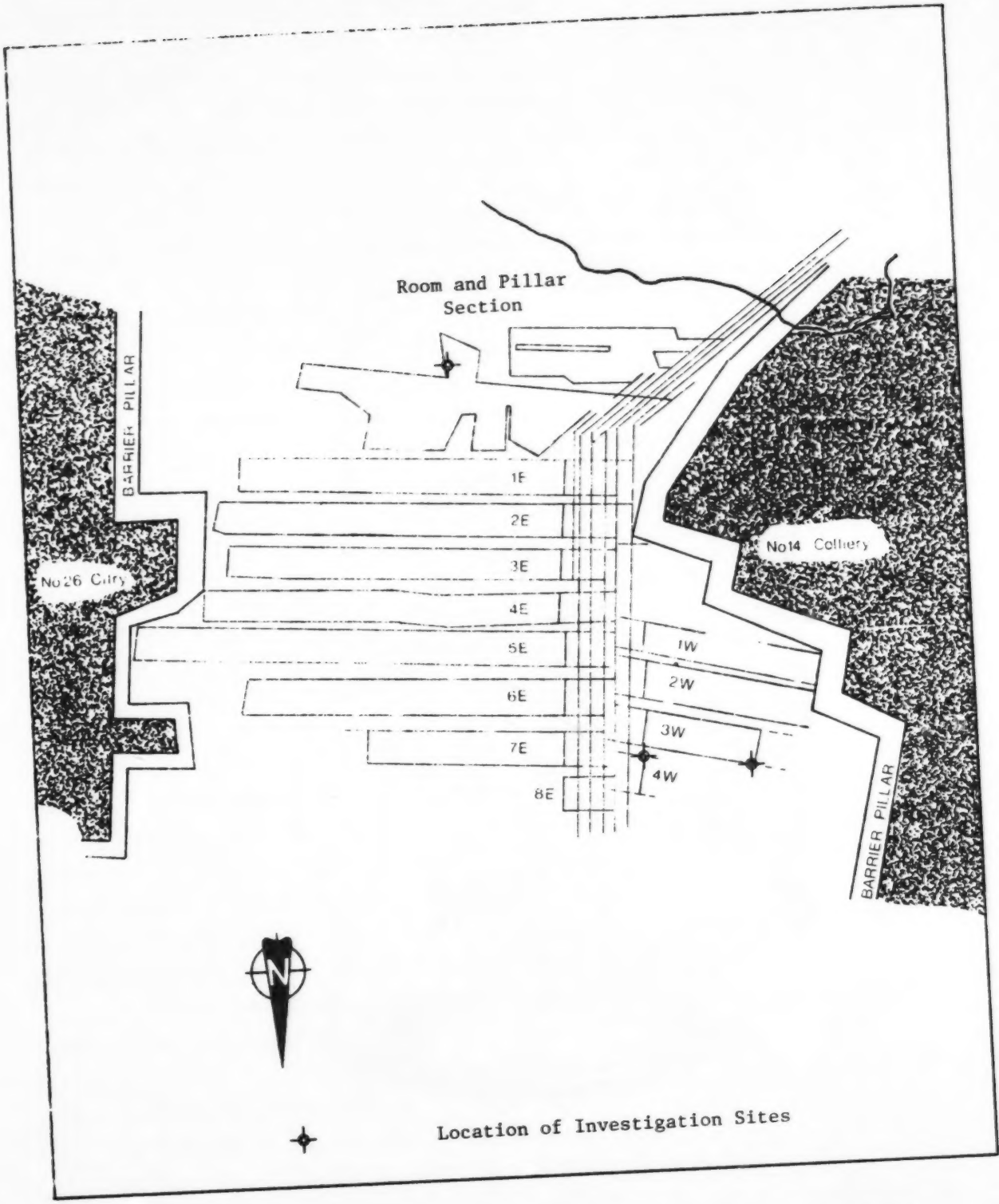


Fig. 2 - Layout of workings at Lingan Colliery, New Waterford, Nova Scotia

The purpose of these investigations were:

1. to determine if machine noise was effectively filtered out
2. To try to determine the effect on roof strata above a longwall coalface of increasing the setting pressure of a powered roof support
3. To try to detect seismic activity resulting from caving above an active longwall coalface.

Results

Due to the unavailability of an adequate chart recorder, comunications problems and production difficulties being experienced on the 3W face, the results obtained were disappointing. They did indicate, however, that under the conditions existing in the room and pillar section, the microprocessor effectively filtered out the machine noise, even when one machine, a roof bolter, was operating within 15 m of the sensor.

Trials on and around longwall faces gave little useful information, except that levels of background noise were higher on 3W, the working longwall, than on 4W, an adjacent longwall under development and installation. Both longwall sections had a higher background level than the room and pillar section.

Recommendations

With the short term future of the room and pillar section at Lingan unsure, and no plans for further room and pillar operations within CBDC, the use of the rock stress monitor would be restricted to longwalls.

In the absence of previous experience in such locations with this instrument, it would be hard to justify its purchase from operational funds.

This does not mean to say, however, that mining-induced micro-seismicity could not prove to be a valuable research tool in the understanding of the caving action and development of subsidence over longwall coalfaces, although current research priorities dictate that the acquisition and deployment of suitable micro-seismic detectors be held back, at least for the time being.

THE ASSESSMENT OF GATEROAD DEFORMATION PROCESSES

Investigations into the deformation processes associated with advancing longwall gateroads were initiated for two purposes. Firstly, to provide a basic understanding of the strata control problems in the Sydney Coalfield, and secondly, to evaluate the performance of pneumatically stowed gateroads.

The decision to install a low pressure pneumatic stowing system on a trial basis in the return gate of the 4W District at Lingan Colliery was expected to make a significant improvement in safety, production and mining costs. Unfortunately this initial installation had to be withdrawn after only four weeks of operation due to production difficulties with the stower and elsewhere in the mine, but it is anticipated that further attempts to implement pneumatic stowing of gateside packs will be made in the future. In the meantime, the investigation of conventionally stowed gateroads will be continued and expanded to provide background data for future packing systems trials.

The current investigation, in the return gate of the 3W District (Fig. 2) was originally installed to allow comparisons to be made between hand-packed and pneumatically stowed gateroads in similar geological environments. The investigation design philosophy has been described elsewhere (2), and so only installation details and results obtained to date will be described, along with a brief discussion of their significance.

Installation Details

The installation of the instrumentation site was carried out largely as planned, but with the following minor modifications:

1. In order to minimize disruption to production operations, both the strata bolt section and the pack instrumentation section were installed at the same time over one weekend, resulting in a distance between them of 6.5 m.
2. The strata bolt section was installed as planned except that the drill steel for the 3 m hole broke on its first use, and subsequently only 1 m, 2 m and 2.5 m bolts were installed.
3. The position of the cribs in the pack made it impossible to install the flat-jacks as planned, and only four were set.

The instrumentation as installed is shown in Fig. 3. Installation of the site, including transport of the equipment from the surface, took two days and employed seven men; three drillers to install the strata bolts, two CBDC mining engineers to observe the installation and liaise with mine personnel and two CBCRL scientists involved in the installation.

Results

Monitoring of the investigation site was carried out each day for the first week after installation, twice weekly for the two following weeks, and thereafter weekly.

Unfortunately, several setbacks curtailed the expected amount of data. Lagging of the arches obscured two of the ribside bolts (Bolts 9 and 10), and one pack strut (Pack Strut 2) was removed by the brushing crew on night shift, despite attempts having been made to explain the purpose of the instrumentation to the shift overmen. In addition, both remaining pack strut reading points were buried, and consequently no readings were obtained.

More disappointingly, the Flat Jacks were vandalized by cutting off the readout unit connections and the identification tags, restricting the amount of information obtained.

In addition to readings from installed instrumentation, determinations were also made of arch leg penetration at an arch adjacent to the strata bolt section (Arch 896) and arch profile deformation.

Arch leg penetration measurements taken from different arches at intervals behind the coalface were taken for comparison, and it is anticipated that a similar survey of arch profile deformation will be undertaken in the near future.

Observations made at the face-end during visits to the investigation site are also described, and their relevance discussed. Results are presented under the following headings:

1. Differential Strata Movement
2. Gateroad Profile Deformation
3. Support Loading

Differential Strata Movement

Differential Strata Movement was determined from strata bolts of different lengths anchored at different horizons above and below the gateroad, as previously described. Results obtained for a period of four weeks after their installation (representing 84 m of face advance) are shown in Fig. 4. Bed separation in the roof and floor was negligible, as can be seen from Table 1.

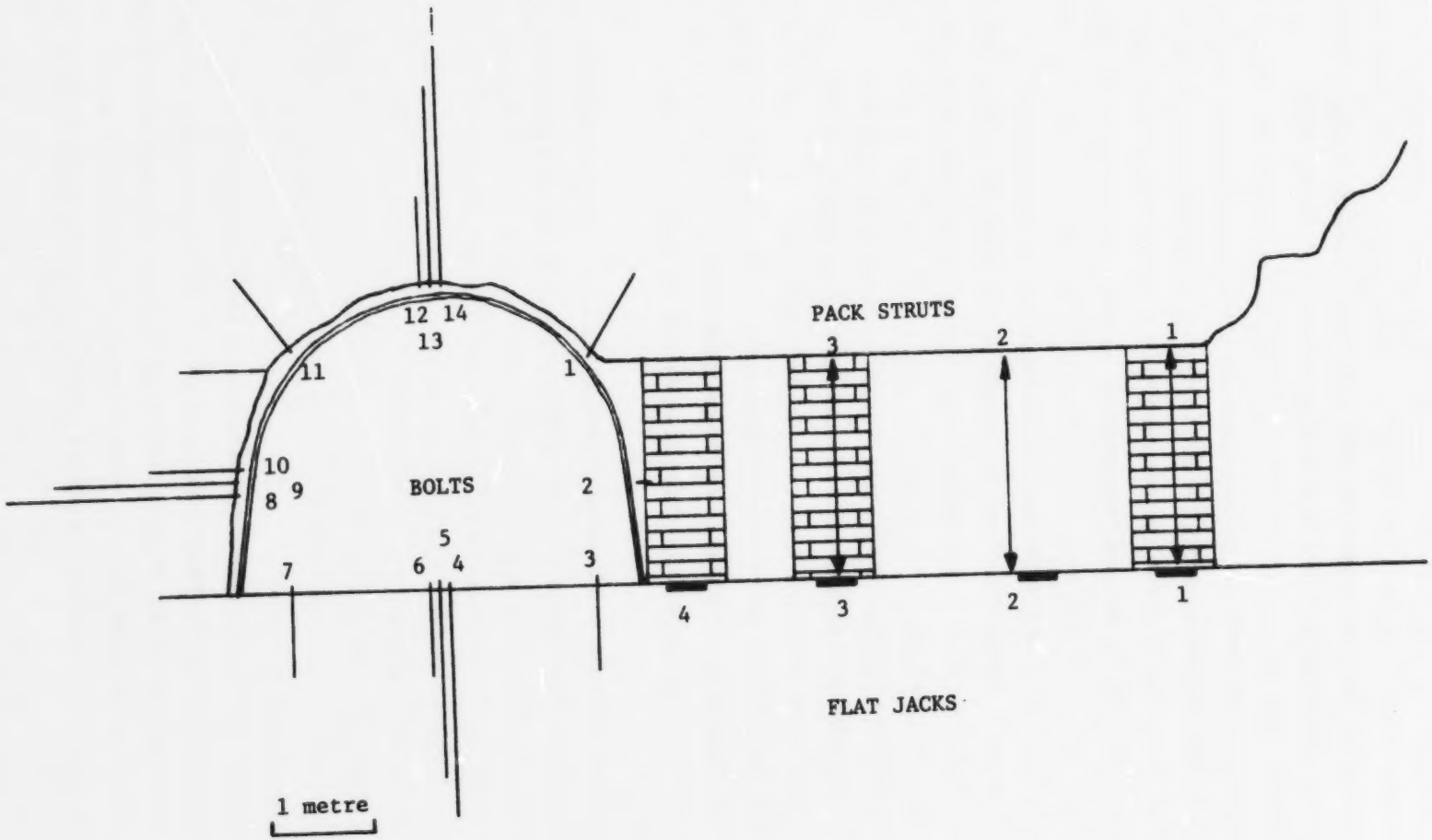


Fig. 3 - Instrumentation installed in the 3W Return Gate Lingan Colliery

Gateroad Profile Deformation

Gateroad profile deformation was determined from regular readings of strata bolts installed as described. In addition to these measurements, the arch profile at the bolt section was determined at installation, and after one month (representing 84 m of face advance). Penetration of arch legs into the floor was determined at the site, and a survey of arch penetration at intervals along the gateroad to a distance of approximately 70 m behind the ripping was carried out.

Strata bolt results are illustrated graphically in Fig. 5, and summarized in Table 2.

Results of the survey of floor penetration are illustrated in Fig. 6. Also included are measurements of floor penetration taken at the site, and total roadway closure as determined from measurements between bolts 4-14 for comparison.

The change in the arch profile of Bar 896 between installation and the most recent reading (31 days after installation) is illustrated in Fig. 7.

Support Loading

For reasons explained previously, results from support loading instrumentation have been obtained only intermittently. Such results as have been obtained are illustrated in Fig. 8.

Discussion

Results so far obtained from the installation reveal much information about the process of deformation.

So far as can be determined, both the roof and floor appear to be competent, exhibiting little differential movement between the anchors of the roof bolts.

The pattern of gateroad closure is characteristic in that the convergence curve indicates two stages of convergence affecting the 3W Return Gate. The first stage is characterized by a rapid rate of closure immediately behind the coalface in the zone of active mining and support operations. This stage appears to extend to approximately 46 m behind the coalface, by which time 81% of the convergence to date had occurred (Bolts 14-4). This represents an averge convergence rate of 3.26 mm/metre of face advance or 8.33 mm/day.

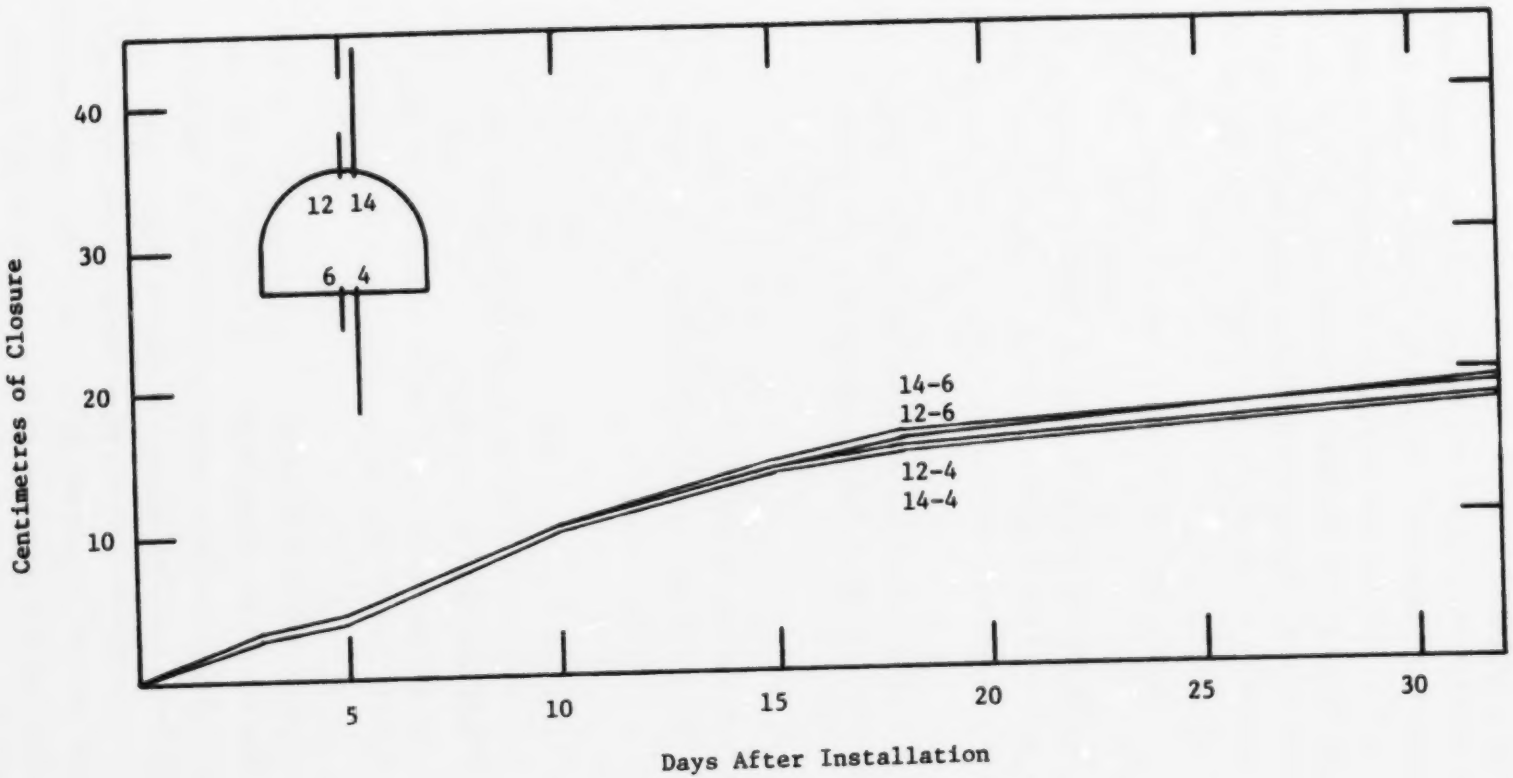


Fig. 4 - Differential strata movement in the 3W Return Gate Lingan Colliery

Table 1 - Summary of differential strata movement in the 3W Return Gate

Separation horizon	Total movement
1.0-2.0 m above roof	-6 mm
2.0-2.5 m above roof	+9 mm
1.0-2.0 m below pavement	Nil
2.0-2.5 m below pavement	-15 mm

Table 2 - Summary of strata bolt results in the 3W Return Gate

Bolt pair	Total closure
12.6	200 mm
11.4	20 mm
1.4	400 mm
8.2	160 mm
11.7	3 mm
1.3	240 mm

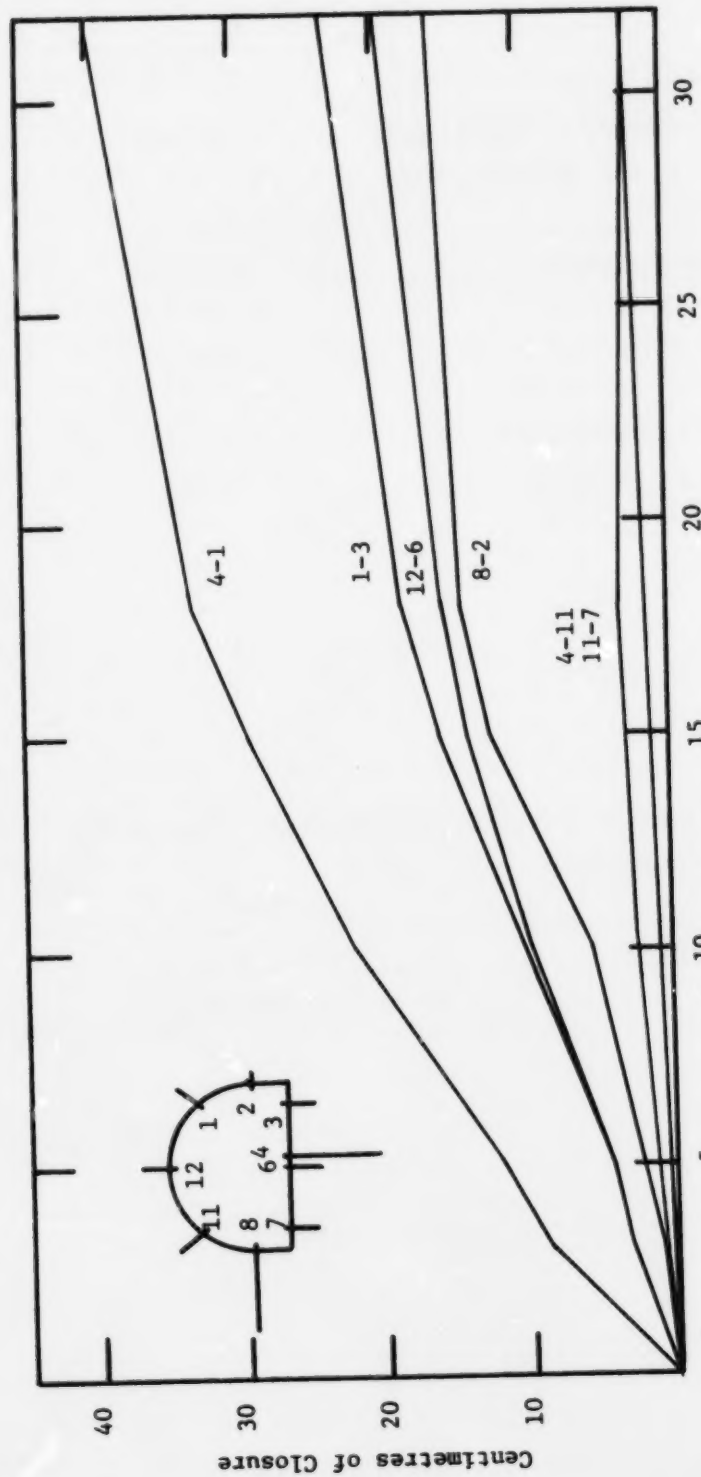


Fig. 5 - Strata bolt results from the 3W Return Gate, Lingan Colliery

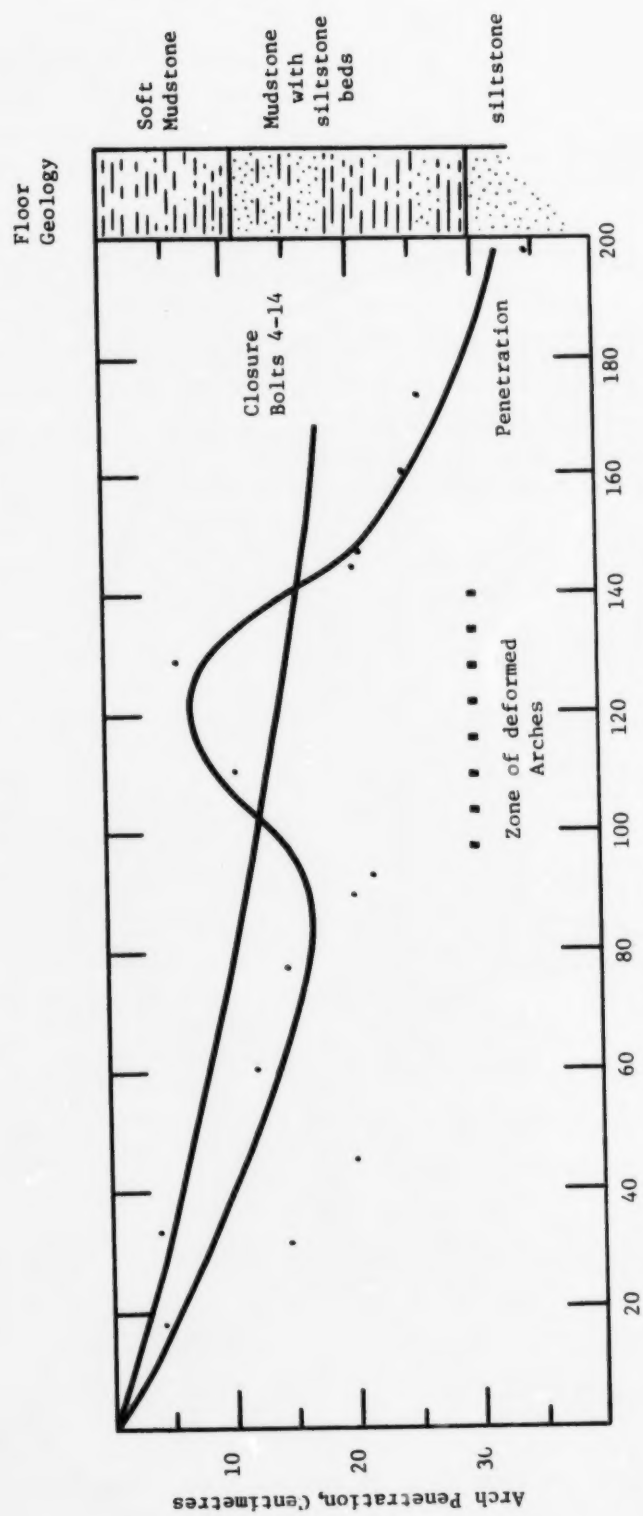


Fig. 6 - Floor penetration survey results

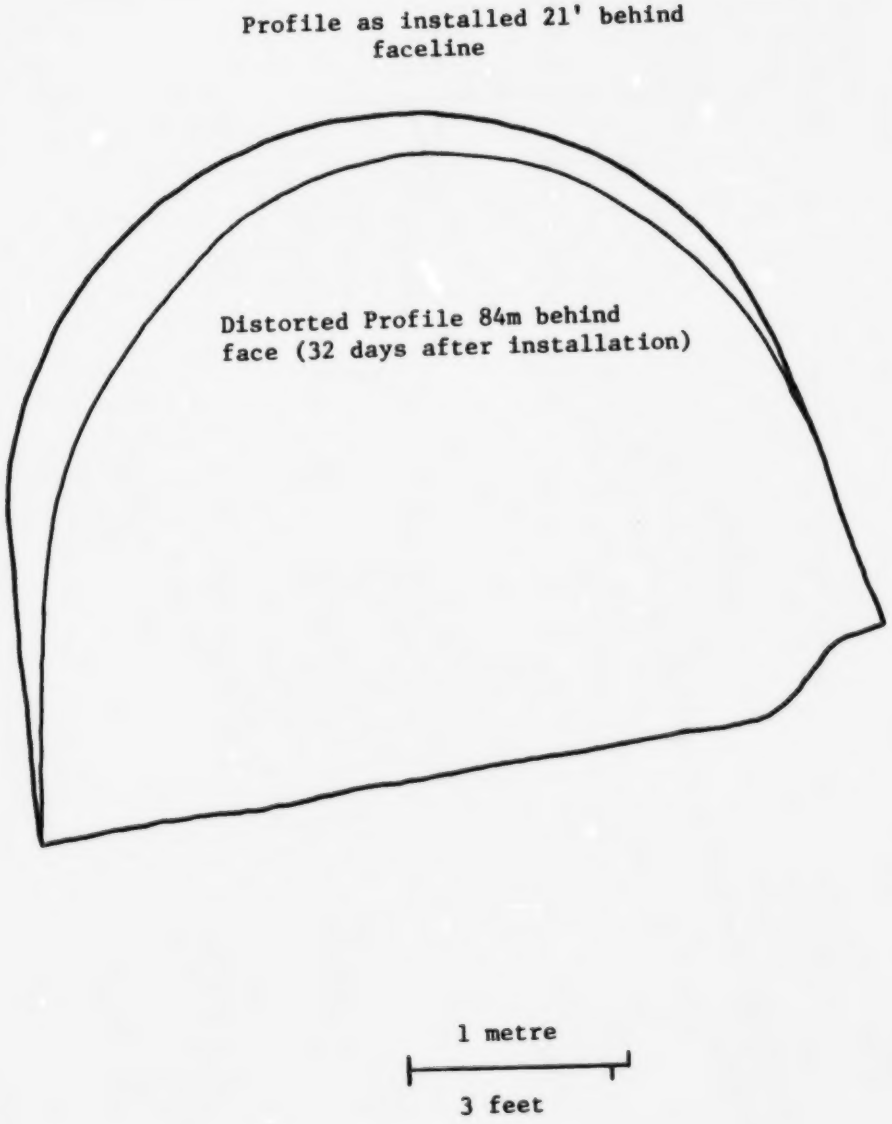
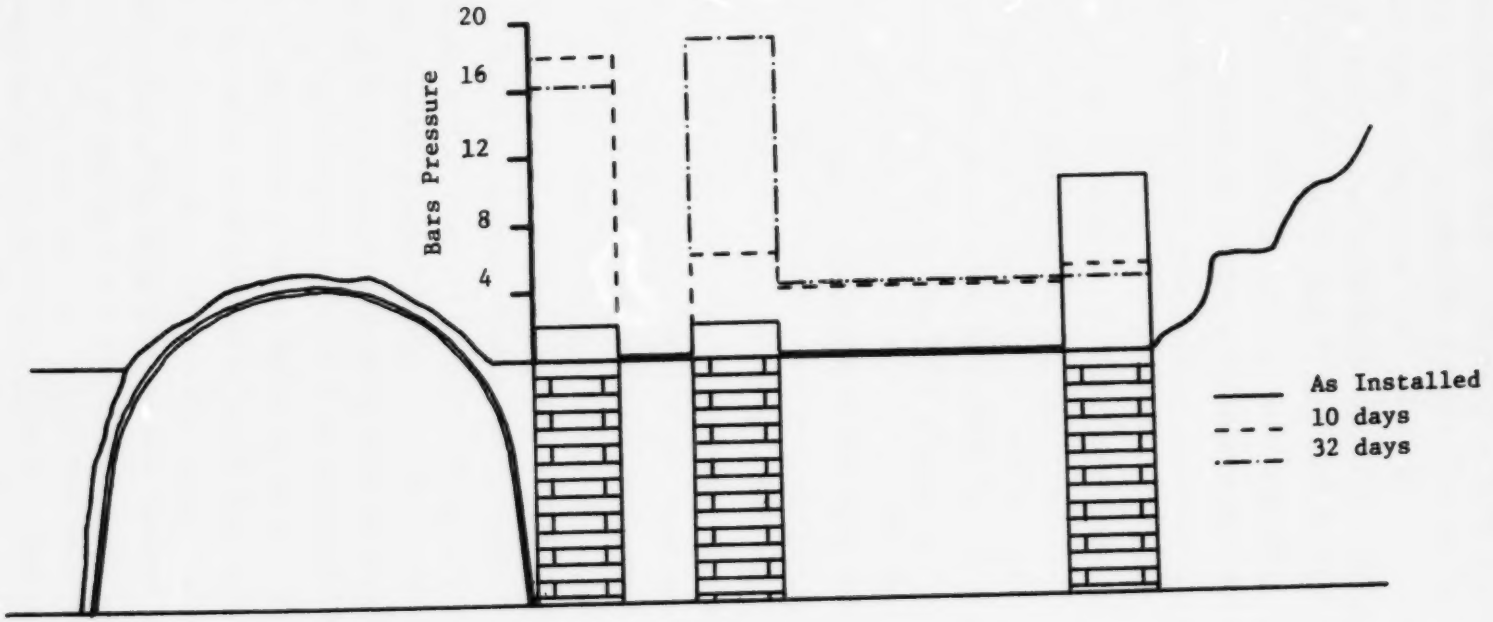


Fig. 7 - Arch profile deformation at arch 896, 3W Return Gate, Lingan Colliery



1 Bar = 14 p.s.i.

Fig. 8 - Support loading in the 3W Return Gate, Lingan Colliery

The second stage is characterized by a slower convergence rate, which in the past has been considered as time dependent. This time dependent closure so far amounts to 19% of vertical closure, an average rate of 0.88 mm/m of face advance or 2.39 mm/day (Bolts 14-4). All convergence measurements exhibit this two stage behaviour, although convergence rates differ slightly.

Bolt results as illustrated in Fig. 5 show slight discrepancies due to reading errors caused by different observers and obstructions in the gateroad. The trend of increasing convergence from ribside to packside resulting from the pivoting of overlying strata at a point some distance into the rib is, however, clearly shown.

Arch deformation has been restricted by the penetration of the arch legs into the floor (Figs. 6 and 7). Figure 6, illustrating the comparison between arch penetration behind the face and convergence shows their similarity. Figure 7 shows the arch deformation exhibited at Bar 896. In a length of gateroad where arch penetration was restricted, (Fig. 6) arch deformation was noted to be more severe.

Other zones of severe arch deformation occur along the gateroad. These may be due either to geological features - harder floor strata, perhaps due to sandstone channels in the roof - or to mining features - poor shearer horizon control removing the soft immediate floor layer and causing the arch to be set on the lower, harder band (see Fig. 6).

Arch deformation is more severe on the pack side, especially at the 'shoulder' of the arch. This is typical of a gateroad with a weak pack. Support loading, illustrated in Fig. 8 shows clearly the transfer of early load on the gobside 'breaker' crib to the roadside and centre cribs and subsequent load development. The late reduction in the load on the roadside crib and transference of this to the centre crib as the roadside crib fails is also illustrated. It is the increase in load at the roadside edge of the pack which causes the typical arch deformation.

The only real remedy to this is to put on a stronger pack. The disadvantages of hand-filled packs from a strata control aspect are well known, although it is accepted that at present there is no strata control problem as such in the 3W Return Gate. Several observations made whilst taking site readings suggest that roadway cross section could be improved by a certain amount of 'fine tuning'.

It was observed that whilst the amount of ripping taken was fairly constant at 1.2-1.5 m, the pack widths varied widely, from 3.96 m to 4.95 m, and that much material was left on the floor after brushing was completed.

Allowing for 10% overbreak on ripping and a bulking factor of 1.5, maximum pack widths should be 3.98 m or 4.9 m for 1.2 m and 1.5 m rippings respectively (Appendix A).

Recommendations

Although the 3W Return Gate is relatively stable, the following 'fine tuning' would bring benefits in pack filling and cross sectional area behind the faceline.

1. Pack width should be brought more into line with brushing height; 3.3 m for a 1.2 m brushing, 4.1 m for 1.5 m brushing.
2. More efficient clearing of the pavement should be practised. This would not only increase the vertical height by approximately 15 cm adding an additional area of the order of 0.6 m^2 to the roadway thereby reducing roadway resistance.
3. No. 3 recom mining.

PRINCE MINE

Since it opened in 1975, Prince Mine has suffered from strata control problems, principally roof falls. The dangers posed to the workers and the reduction in coal production as a result of these falls caused great concern. In response to these concerns several efforts were made to determine the cause of the roof falls. The recent establishment of the Cape Breton Coal Research Laboratory to investigate, among other things, strata control problems in the coalfield, has brough fresh impetus to these studies and an opportunity to review the progress made to date.

A REVIEW OF ROOF FALL STUDIES

Investigation of the roof falls by CBDC geological staff[3] revealed that most of the roof falls at Prince Mine were associated with the pinchout of a sandstone unit lying above the roof of the coal seam. The locations of such roof falls are shown in Fig. 9. A schematic section through the problem

areas is illustrated in Fig. 10. The investigation report recommended that comprehensive diamond drilling and geological mapping be carried out to determine the extent of the troublesome areas, and that the program be extended to give adequate warning of the impending return to such conditions.

In 1981 an investigation by Wang et al[4] conducted at the request of CBDC, found no link between the roof falls and vibrations transmitted from two strip mines working nearby. This report concluded by recommending "that a strata mechanics study be undertaken at Prince Mine to determine the causes of the roof instability problems and assess courses of corrective action", and recently Gyenge[5] has outlined a Laboratory test program to determine the physical and mechanical properties of Prince Mine proximate strata as a preliminary to the evaluation of existing roadway support systems.

Roof Fall of November 2nd 1982

On November 2nd 1982 a roof fall was experienced in Number 2 Slope at Prince Mine (Fig. 9). The fall occurred in an area underlying the pinchout of the lower sandstone member (Unit II, Fig. 10) and as such was identical in occurrence to falls experienced between 1975 and 1977 (op cit). The fall resulted in the collapse of approximately 10 m of roadway and left about 70 tonnes of rock to be cleared.

Of particular importance was the fact that the slope, originally driven with a rectangular cross-section, had recently been ripped by a roadheading machine and resupported on arches. In addition, this latest incident was adjacent to a previous fall which occurred in April 1977 and was localized, in part at least, by a four-way intersection.

A visit to the fall area on November 5th 1982 revealed several interesting features summarized in Fig. 11.

It may concluded that the roof of the area was unstable at the time the arches were installed, a situation which was compounded by the cutting through of the Lower Sandstone (Unit II) and the failure to support the intersection at the time of arching. The lateral extension of the fall was terminated by two discontinuity planes, one a relic of the previous fall and the other a natural joint plane. The upper limit of the fall was the base of the Upper Sandstone (Unit V) which was the next highest competent beam.

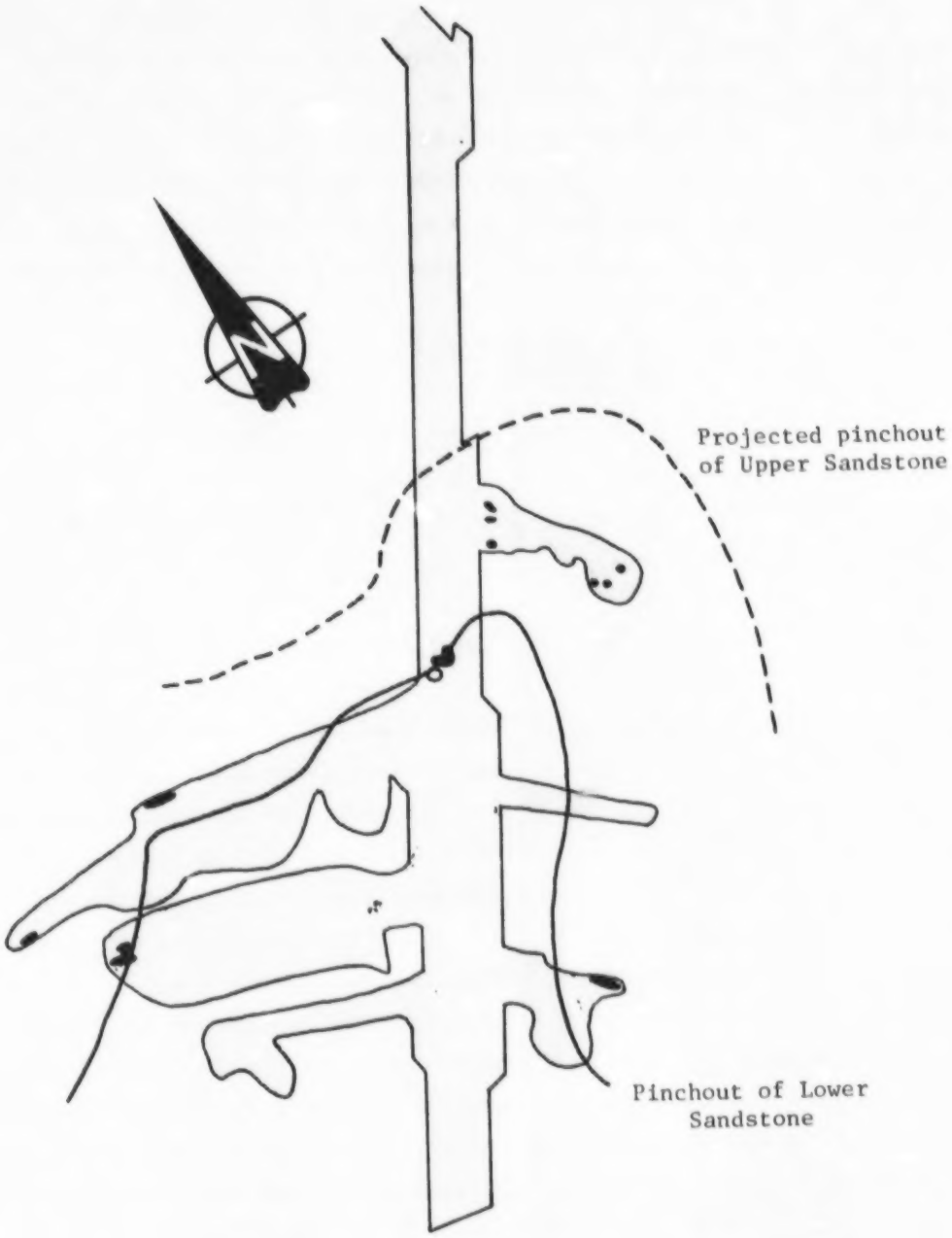


Fig. 9 - Roof fall locations at Prince Mine

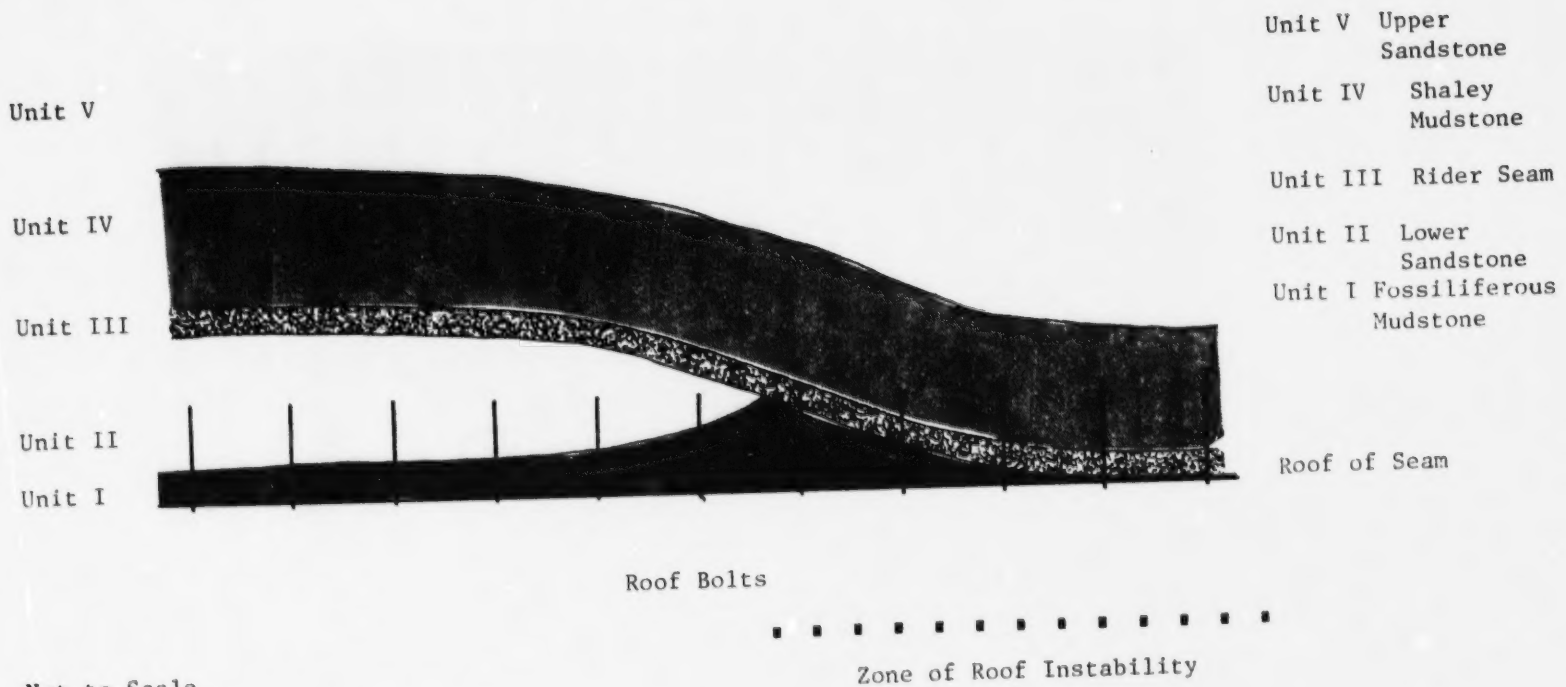


Fig. 10 - Schematic section through the roof fall zone at Prince Mine

Future Activities at Prince Mine

Of major importance will be the investigation of the roof instability problem. Various aspects will be considered, including the effects of weak floor strata on support effectiveness, and the prevention of instability by improved roadway design. In particular an assessment of the stability of arch sections and rectangular sections of greater than seam height (required for ventilation) at various positions in the strata column will be undertaken.

NO. 26 COLLIERY

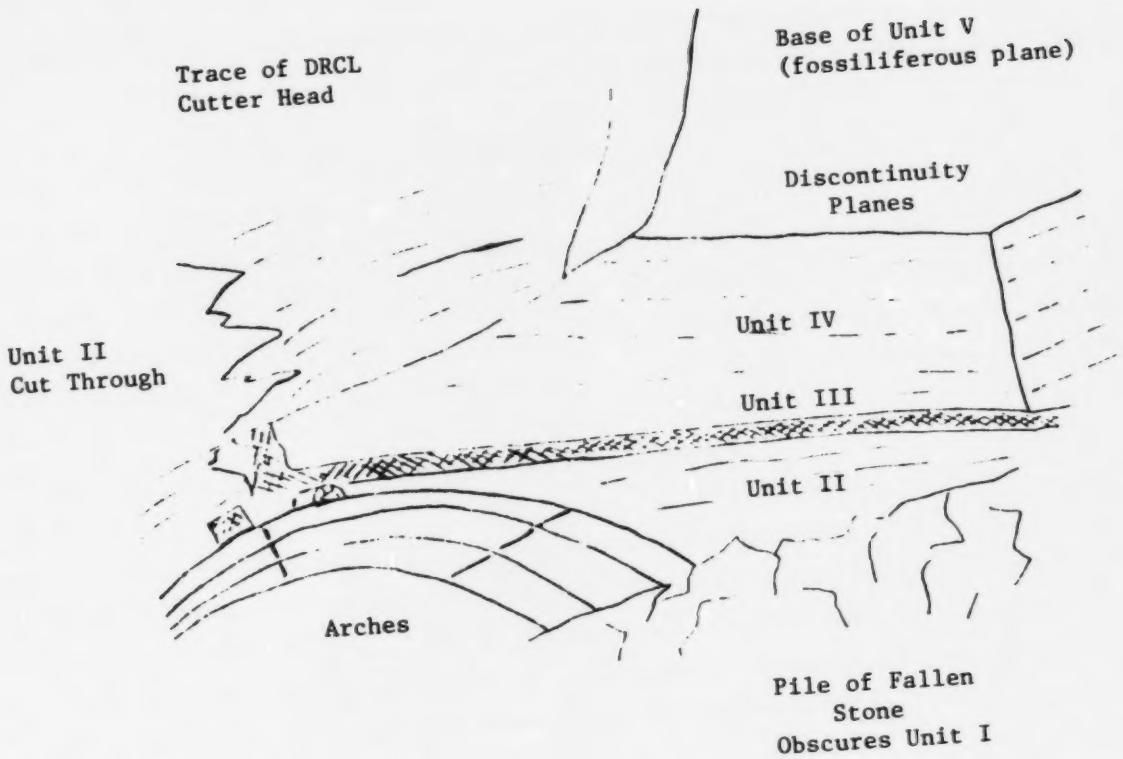
To date no assessment of strata control problems has been made at No. 26 Colliery, although since the withdrawal of the Pneumatic Stower from Lingan this has received a higher priority and will be a major objective in the next quarter.

THE DONKIN-MORIEN PROJECT

In August 1982, an unsolicited proposal was submitted by Golder Associates to the Department of Supply and Services for a rock-support interaction study at the Donkin-Morien Development Project. Golder Associates are the geotechical consultants for the mine access tunnels. At present, the proposal is in the final stages of negotiation and should be ratified in the near future.

The proposal involves monitoring the deformation characteristics of the strata around the two access tunnels currently being driven, one by conventional drill-and-blast methods and the other by a 7.6 m diameter Tunnel Boring Machine (T.B.M.). Additionally, in situ stress measurements and the determination of physical and mechanical strata properties will be carried out to provide basic data for numerical analysis of the deformation process.

Current CBCRL involvement in the Donkin-Morien project is limited to a study of minor water inflows which have been experienced in several sections of the No. 3 Drill and Blast tunnel. All available data concerning the inflows has been collected and is currently being re-assessed. However, it is hoped to extend the scope of the data collection programme and use alternative analytical techniques to determine the original source horizons.



Not to Scale

Fig. 11 - Principle features of the roof fall of Nov. 2nd 1982 at Prince Mine

OBJECTIVES FOR THE QUARTER TO MARCH 31, 1983

Objectives for the quarter to March 31, 1983 involve the consolidation of present activity and the assessment of areas for future expansion. The main objectives set for each colliery are listed below.

LINGAN COLLIERY

Monitoring of the existing site will continue. Other sites will be installed in the same gateroad to give additional information about the behaviour of the hand-filled pack and to confirm the convergence trends shown.

Cored borehole drilling will be undertaken in 3W District to provide information about proximate geology and to obtain samples for physical and mechanical properties testing.

Gateroadway investigations will be extended to other districts, probably 4W and 7E, as time and opportunity permits, in order to gather more information on gateroad deformation processes.

Prince Mine

Cored borehole drilling will be undertaken at several locations in Prince Mine to provide details of proximate geology and to obtain samples for physical and mechanical properties testing. Information obtained will ultimately be used in conjunction with mathematical modelling techniques to try to determine a solution to the roof instability problems experienced at the mine.

Number 26 Colliery

Activity at Number 26 Colliery will be restricted to an initial assessment of strata behaviour and the definition of any ground control problems prior to the development of an experimental approach to assist in their solution.

The Donkin-Morien Project

Assuming that the unsolicited research proposal from Golder Associates is accepted, activity on this project will involve the installation of one or possibly two investigation sites in Number 3 slope (driven by the drill-and-blast method). These sites will provide information on tunnel de-

formation processes for comparison with sites to be installed in Number 2 Slope (driven by a Tunnel Boring Machine).

Analysis of water inflow data from Number 3 Slope will continue and methods of determining the source of the water will be assessed and implemented.

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APPENDIX A

FACE END OPERATIONS IN THE 3W MATERIALS ROAD, LINGAN COLLIERY

Optimum pack widths quoted for ripping heights of 1.2 m and 1.5 m are 3.38 m and 4.09 m respectively, based on an overbreak factor of 10% and a bulking factor of 1.5. Actual pack widths compare unfavourably with these theoretical values, being between 3.9 m and 4.8 m.

Measurements made on December 9 and 21, 1982 revealed that the average overbreak at the ripping was 110%. Optimum pack widths under these conditions would be 4.01 m and 5.13 m for 1.2 m and 1.5 m rips respectively.

Although these results appear more comparable with actual pack widths, the practice of taking a 110% overbreak at the ripping lip has serious consequences both in terms of economics and ground control. These are summarized below:

ECONOMIC CONSEQUENCES

- more man/hours are required to move the broken material into the packhole. For a 100% overbreak, the cost of packing the material will be doubled.
- more explosive is used than is required
- more wood blocking is used in backfilling the arch, and the backfilling operation itself takes appreciably longer.

Ground Control Consequences

- the use of larger quantities of explosive contributes to weakening of the face end by increasing the fracture of the rock around the arch
- backfill is not as efficient in support as solid rock
- yield zone extends, allowing increased convergence at the face end
- irregular backfilling leads to point loading of the arch, hence incresed deformation.

Other Consequences

- more roof is exposed at the brushing, increasing the hazard to workmen

- the higher explosive charge required to bring down the ripping will enhance fracturing around the entry leading to increased gob leakage
- larger quantities of explosive per hole increases the likelihood of flame shots and other blasting incidents.

Thus there is an appreciable need for a review of face end operations. Such a review should cover current face end practice at all the advancing headings in CBDC mines and survey the extent of the problem.

An obvious method of improving face end practice would be to design and implement an alternative blasting pattern utilizing larger numbers of holes and smaller charges per hole. Increased drilling time could be offset by drastically reduced packing and backfilling time and the acquisition of better drilling equipment.

Ground control at the face end would be improved, gob leakage reduced and productivity increased.